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Techniques of Generalisation In Computer-Assisted Cartography In The Realm of Artificial Intelligence

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Abstract

Generalisation has been a major component of the cartographic method. The principles and practices of generalisation of cartographic elements in an automated system should not be assumed to be the same as those in manual cartography. In this paper an appraisal of the techniques and problems of generalisation, especially relating to those presented by computer technology, are advanced together with some reference to artificial intelligence and requirements of future tools for the provision of solutions to the problems.

1.0 INTRODUCTION

Generalisation belongs to the most important concepts in cartography. It is the fundamental ingredient in the preparation of maps because of the necessity of retaining legibility as the scale is reduced. In most cases the method adopted has been empirical and subjective; theoretical approach have been considered since the introduction of computers in cartography.

The introduction of computer-assisted cartography has put forward the problems of formalisation of all generalisation methods. Computer-assisted cartographic generalisation depends upon the separation of technical factors from those that are subjective in nature.

With due regard of generalisation objectives, this paper discusses possible techniques and solutions that have been proposed in the literature and to relate proposals to the availability and the capability of the present technology. Artificial Intelligence approaches in generalisation will be included in the discussions.

In compiling any map, decisions must be made as to what information to be shown and how it would be represented. For example the creation of small scale maps from larger scale cartographic sources requires reduction of details to accommodate the small space available for representation, this involves cartographic generalisation.

The need for generalisation comes from two different sources: 1. reduction of natural and cultural features in accordance with the scale of the map and the difficulty of symbolisation many of these features precisely at small scales; and 2. communication of the relationship underlying observation of geographic phenomena through elimination of unnecessary detail or exaggeration of important details.

During scale reduction, generalisation usually is thought of as smoothing character without a reduction of information content. Attempting to reduce scale without generalisation can produce a map with a level of detail too great to be understood by the user. Actually generalisation is a necessary component in maintaining a high level of general information on a map..

2.0 THE DEFINITION AND CONCEPTS OF GENERALISATION

The general concept of generalisation have been thoroughly discussed in literatures by such authors as Imhof (1965, 1972) Steward (1974), Robinson et al. (1978), Swiss Society of Cartography (1975), and other leading authors. Robinson and his co-authors group generalisation into four categories of process termed 'elements' of generalisation : simplification, classification, symbolisation and induction. They defined that feature selection is not a part of cartographic generalisation. The application of these processes is dictated by the so called 'control' of generalisation including objective, scale, graphic limits and quantity of data.

Steward (1974) compiled a list of terms frequently used to describe generalisation activities as :

- select, eliminate, delete, omit (selection)
- simplify, classify (simplification, classification)
- symbolise, emphasise, enlarge, exaggerate, amplify (symbolisation)
- summaries, combined (induction)

In a review of approaches to automated generalisation Rhind (1973) compiled a list of process which have to be handled by generalisation system;

Line sinuosity reduction

- simple selection
- complex selection
- tolerance
- reduction through averaging
- angular deviation of line measures
- arc substitution
- frequency component filtering
- feature transposition

Amalgamation

- within categories
- between categories
- nominal classification
- evaluation of numerical characteristic data

Elimination

- entire feature types
- within feature types

Graphic encodings

Christ (1976) discussed procedures of generalisation as a function of six primary operations:

- selection
- simplification (reduction of sinuosity)
- variation of quantity (size and line width)
- variation of quality (shape and colour)
- merging of features.

Based on the general concept of generalisation, Brussel (1984) formulated generalisation process in the form of a number of functions which would be implemented as operational steps in a generalisation system. These functions then operated on a number of objects. Based on this function-and-object concept he made a list of operations which are available in an operation of map generalisation system:

"Point Features"

- select point features to certain criteria
- eliminate point features subject to certain criteria
- identify cluster of point of features and create a smooth polygonal outline (integration)
- expand
- clear
- classify
- display

Line Features:

- expand/ shrink/ select/ eliminate
- reduction of sinuosity (using specified method)
- change topology in linear networks
- displace
- clear
- classify
- overlay line networks (intersect. merge etc)
- reduced
- display

Area Features:

- select
- eliminate
- expand/ shrink
- reduced sinuosity of outline
- classify
- change of topology
- displace
- clear
- overlay (logical and arithmetic operations)
- convert to raster/vector format
- replace area features by line/point features
- display

Some of the process above not only operate within their groups but among other groups as well.

3.0 ARTIFICIAL INTELLIGENCE

A considerable body of literature exist on approaches for computer-assisted generalisation. Software reviews are given by Weber (1982) and Zorasters (1984). Weber (1982) groups recent development of computer supported generalisation into three categories :-

- a) generalisation based on information concepts
- b) the filter-oriented method of generalisation
- c) the heuristic generalisation

Information based concept of generalisation is considered superior to the other two categories, since the latter quite often represent symptom treatment and not based on a through understanding of the

generalisation process. Weber (1982) reviews a number of algorithms developed for line smoothing, point amalgamation, object selection (point, line, area objects), object clustering and object displacement.

Zoraster, Davis and Huges (1984) have compiled a review of procedures of manual and automated line generalisation and feature displacement. A preliminary elimination and guide lines for future developments were presented in the literature. For large number of desirable generalisation tasks no algorithms have been developed yet, and further progress may be promoted.

Attempts have been made to automate the ways in which a cartographer makes judgement about which features to keep and which ones to ignore. Artificial intelligence method can in theory be used to teach a programme recognition skills to do this. In reality this attempt to duplicate is very complex procedure. Other methods try to evaluate the importance of features mathematically. This is also in fact, a non trivial solution with many special cases. Neither approach represents a simple generalisation solution.

Due to complex nature of generalisation a fully automated solution may not be attainable at present. Displacement has proved to be computationally intensive task even considering a small number of features (see Zoraster and Huges, 1986). Generalisation has been perceived as a more tractable problem, but this is due to the failure to consider the generalisation of features rather than lines, then association among features and the development of representation patterns using exaggeration relocation. Efforts should be directed towards improving the present algorithm and developing advance iterative edit techniques for resolving reading problems. Fully automated techniques may develop with advance in artificial intelligence (see Caldwell, 1985).

3.1 Expert System

The goal of artificial intelligence-based system is to produce programmes that imitate human performance in a wide variety of intelligent tasks. Although this goal is still far away some problem solving computer programmes have already reached a rather high level of performance for some small and well defined application areas (e.g. medical diagnosis, mineral explorations and etc.) (see Nau 1983).

Expert systems have been extensively received in the specialist literature from which a number of keynoted books can be referred. They have also been the subject of recent article in the geographical and environmental sciences literature-navigational route mapping, etc.

Robinson and Jackson (1985) discussed their joint paper of a formal definition of expert systems approved by the British Computer Society Specialists. The definition is given as :- "An expert system is regarded as the embodiment with a computer of knowledge-based component which form an expert skill in such a form that the system can offer 'Intelligent Advice' or to take an 'Intelligent' about a processing functions. A desirable additional characteristics which many would consider fundamental is the capability of the system on demand, to 'Justify' its own line of reasoning in a manner directly intelligent to the engineer. The style adopted to attain these characteristics is 'Rule-based Programming' (Robinson and Jackson, 1985).

Nau (1983) stated that the main difference between expert system and ordinary application programme is the representation of problem-solving knowledge. In expert system this knowledge is usually handled explicitly as a separate entity name the knowledge-based and not contained implicitly as part of the programme code. This knowledge base is manipulated by its own control strategy. Thus expert system organised on four levels: data, knowledge and meta rules (Nau 1983, Ranziger, 1985). Ordinary computer programmes organised on two levels: data and programmes.

On data level there exists declarative knowledge about the problem being solved. The knowledge

based level contains knowledge specific to the particular kind of problem that the system is set up to solve. For different application, the data based and knowledge based are not strictly separable (eg. parts of maps). Data based can be used for knowledge based objects recognition in aerial or remotely sensed imaged (Nau 1983).

Procedural knowledge comprises of a collection of methods and procedures which can operate on elements of knowledge based and data base. The control structure is responsible for selecting the appropriate rules and data for solving a given problem (Ranzinger, 1985).

As suggested by Pfefferkorn et al (1985) in their joint paper titled 'Cartographic Expert System' cartographic generalisation heuristic could be achieved by identifying what expertise was required by the cartographers to successfully generated a map. How is the worked planned?. What generic and specialised techniques are considered, and why specific ones are chosen over the others?.

The knowledge required to successfully accomplished generalisation tasks from map to map could be divided into three parts :

- i) general procedural knowledge
- ii) task specific knowledge
- iii) heuristic based ruled of thumb

Mackeness et al (1986) suggested the use of expert system for map generalisation. Expert system is effectively a search problem choosing the generalisation process that satisfies the large number of constraint. This can be done either by application of systematic unguided search procedure (which may be slow to converge to the optimum solution) or by the application of heuristics to the constraint the search procedure, thus reaching the desired goal more quickly.

Any search problem involves the definition of three components :

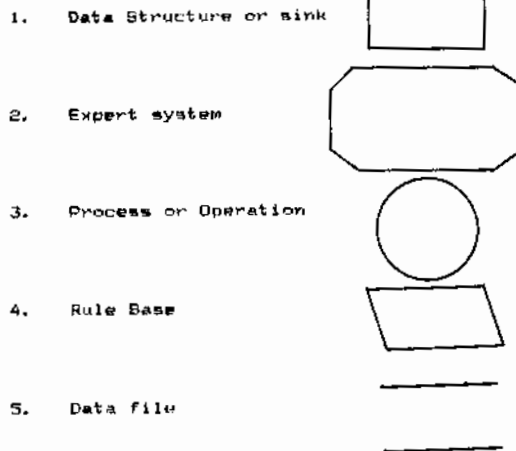
- i) Goal State Description
A quantitative description of permissible map generalisation from cartographic angle. this will involved the definition of acceptable and unacceptable levels of spatial complexity.
- ii) Good Test Function
Functions are required to evaluate the intermediate map generalisation process how near the map is to the optimum goal state.
- iii) Distance Evaluator
this is the function that determined the degree of success that the system had reached the optimum goal.

Each of these components in practise, should be expressed in appropriate quantitative definitions and algorithms related to visual quality. The main difficulty of the automated generalisation process is in quantifying these tasks which presently performed by cartographers. This is a cartographic problem not a computer problem.

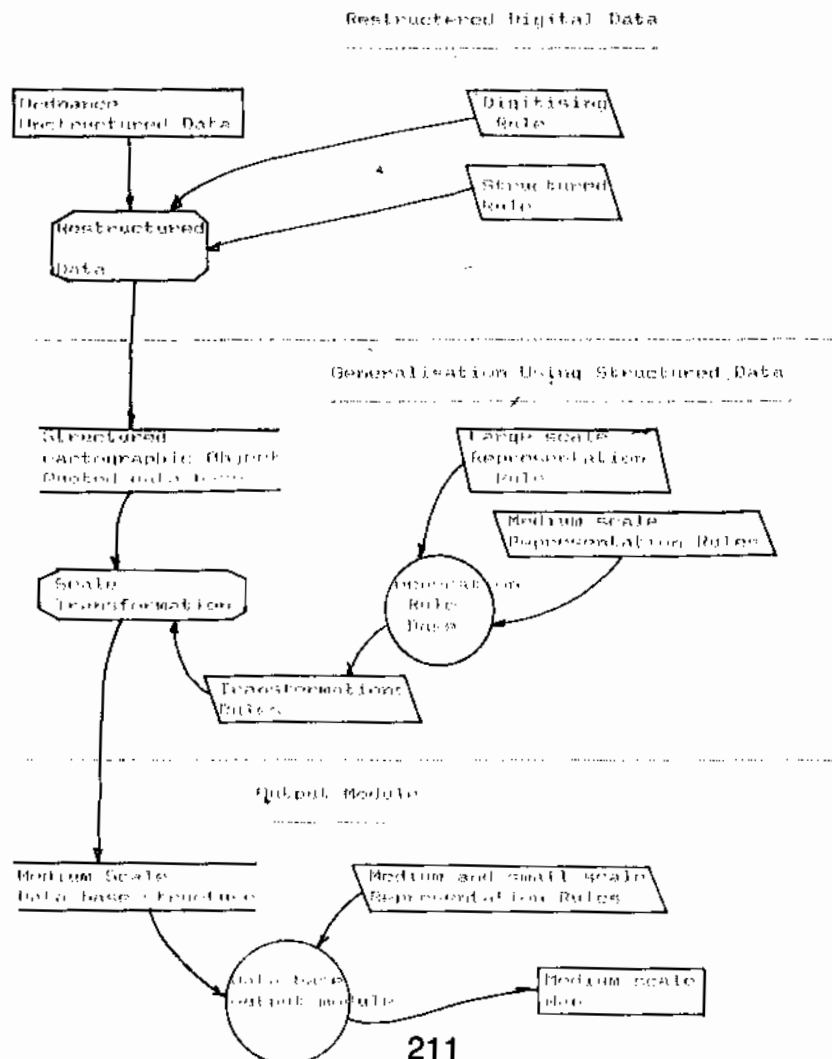
A paper by Vicars and Robinson (1986) on 'Generalisation of Survey Ordnance Map using Expert System Techniques' proposed an approach of generalisation using artificial intelligence. To successfull automate generalisation, the process of generalisation must be fully understood in order it can be turned into computer manageable instructions. As a starting point 'Flow Diagram' of the equivalent automated process was created and computer programs written. Their approach was based upon photo-reduction process and the Douglas and Peuker algorithm of linear features generalisation or

reduction. This approach is equivalent to the generation of strip trees. It envied that these techniques would be applied to reduced linework at large scale (Vicars and Robinson 1986).

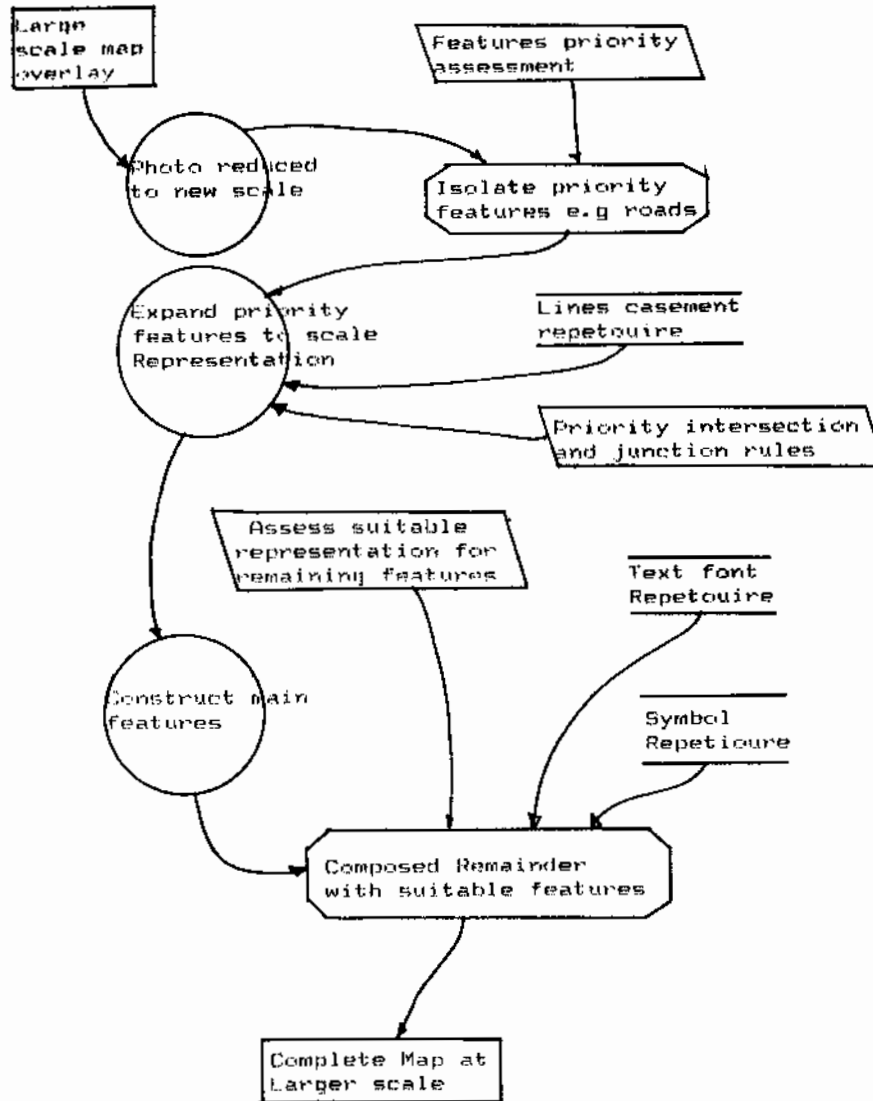
The key to their flow diagram are given :-



Data flow Diagram of Scale Reducing Using Expert Systems Structure (Vicars and Robinsons 1986)



Data Flow Diagram For Manual Reduction With Generalisation
(Vicars and Robinsons 1986)



This process produced a structure appropriated to the new scale and style which is the output by a special output module. This approach is also potential application to data structures and data transfer standards for medium and small scale.

3.0 TECHNIQUES OF GENERALISATION IN COMPUTER-ASSISTED CARTOGRAPHY

In Computer-assisted cartography, two types of computer readable data currently in existence :

- i) data stored as strings of coordinates (mostly the results of digitising), and
- ii) data stored as pictorial elements (remotely sensed or scanned)

All generalisation process can operate on both types of data. Computer-assisted generalisation problems could be solved by reducing the data into small parts or pieces, being small they can be handled in an efficient manner. Generalisation procedures are simplified and the interdependencies are reduced to what are possible. The simplified procedures are mathematically formulated and

computerised. These are the partial solutions to computer-assisted generalisation and their results will be presented in this paper. It is not possible to define a computer programme to do all the generalisation work. Only the routine work of the cartographer could be programmed by the computer and the results from the programme further corrected by means of iterative editing facilities.

There are numerous examples of mathematical connections between real world data and the generalised data on the map. These mathematical concepts which relate the real world to the generalised data on the map do provide an effective means for computer-assisted generalisation process. For example the mathematical concept of curvature permits a reduction in the sinuosity of a line in a uniform and continuous manner as well as the mean to emphasise certain selected features. The idea of mathematical approximations permits the view of a line discretely as a series of x, y coordinates, and concomitantly allows the reduction of the number of features to be portrayed on the basis of specified minimum size.

The cartographic elements exist in reality as points, lines, areas and volume. When data stored as strings of coordinates, the elements may occur as points and lines.

Line features, including contours of areas, a geometrical contiguous sequence of line elements showing the same header. Line elements are a logical continuous sequence of points, becoming connected by the same kind of interpolation when the line is drawn by an automated drafting machine (Christ 1976). If sequence of points are connected linearly the line element is a polygon, if connection is interpolation of higher degree the line element is curve (Gottschalk 1971). Therefore lines may be curved or polygon and also may have form network structures as nodes and edges. In topographic maps lines may represent surface or surrounded areas like vegetation areas. Accumulation of point may form areas. The most common operations carried out in computer-assisted generalisation are feature selections, geometric smoothing of cartographic elements and feature shifting or displacement if their distances get too narrow.

There are many smoothing techniques, which could be applied to lines and surfaces. Line smoothing could be carried out by filtering using arithmetic means, spline, or dropping points of polygons (Jancaitis, 1973). The degree of smoothing could be defined by the final scale of the generalised map. Generalisation accounts for the loss of information and the amount or degree of information loss could be computed through statistical laws. Decisions whether a line is properly smooth or otherwise is determined subjectively by the cartographer. The parameters of the programme were interactively changed until the results of computer-assisted generalisation are acceptable. Examples of curved linear features were contours, roads, vegetation boundaries, etc. They can be smoothed, for example, by means of a gliding arithmetic mean using a special weight functions.

Smoothing polygons may be quite difficult. Usually polygons will form political borders which will coincide, for example with other topographic items like rivers and so on, and if treated independently will have discrepancies in the results. So polygons are a little bit difficult to handle in the computer assistance. There are several methods of smoothing polygons. The first method is by means of dropping some points out of every fourth or fifth points, or considering the length of the edges between the two nodes or the distance of a point from connection between two neighbours. If the distance is below the limit, the point is dropped from the polygon.

The cartographic line elements usually form network of structure surfaces represented by contour lines. These can be simplified by smoothing each contour separately or by smoothing the surface represented.

As mentioned earlier most surface fitting and smoothing routines are simplification techniques. Currently in computer-assisted cartographic, data reduction is sometimes referred to as a separate process in constructing and editing of files from the generalisation process. Data reduction is more

or less the same as simplification process, therefore, should be considered as part of cartographic generalisation and not just data preparation. Many computer algorithms currently exist to aid cartographer in computer-assisted simplification and classification.

Numerous techniques have been utilised for line reduction. These techniques uses computer algorithms or programmes to reduce the number of points required to represent numerically recorded lines. The method can be broadly categorise into three categories namely:- elimination of point along the line by one or more of a multitude of criteria; approximation of line and mathematical functions; and deletion of specific cartographic features represented by lines and so forth (Douglas and Poiker 1973)

4.0 CONCLUSIONS

The success of the techniques and problems of generalisation, especially relating to those presented by computer technology, are advanced together with some reference to artificial intelligence and requirements of future tools for the provision of solutions to the problems has been presented. Any particular expert systems is dependent on the system being applied to a clearly bounded domain of knowledge, and decision within that domain being consequently on a pool of knowledge of ascertained facts. Some of the cartographic knowledge is readily accessible in journals articles and reference works and textbook on cartographic practise.

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